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LAKEWARD MOVEMENTS OF JUVENILE
CHINOOK SALMON AND RECOMMENDATIONS FOR
HABITAT MANAGEMENT IN THE KENAI RIVER,
ALASKA, 1986-1988[1]

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ABSTRACT

The <u>Kenai River Comprehensive Management Plan</u> was developed in 1986 to address urban development along the lower Kenai River. Sampling was conducted for selected habitat and biological parameters necessary to formulate developmental policies for the land use permitting process called for in the plan. Research focused on describing the movements and seasonal distribution of juvenile salmonids, particularly chinook salmon *Oncorhynchus tshawytscha*.

Movements of age 0 chinook salmon inhabiting the mainstem Kenai River were investigated by marking and releasing 90,105 fish in the lower river and examining subsequent minnow and fyke trap catches from the lower 80 river kilometers for the presence of marked fish. Marked chinook salmon were recovered both upstream and downstream from their point of release. Twenty-two marked fish representing an estimated 282 lower-river-origin chinook salmon were recovered near the outlet of Skilak Lake. These fish migrated upstream approximately 56 kilometers during a 10 to 14 week period in the fall. Marked fish that were recovered near Skilak Lake were significantly larger than those which remained in the lower mainstem. The use of Skilak Lake for rearing and overwintering by age 0 chinook salmon is indicated by the presence of this species in minnow and fyke trap catches from sites within the lake. The exodus of salmon from mainstem habitats during the fall results in abrupt declines in chinook salmon catch rates and relative abundance, and correlates with commensurate declines in stream discharge and water temperature.

A review of recent studies on habitat preference suggests that cover and velocity conditions best describe habitat usability for age 0 chinook salmon; however, these conditions do not appear to be limiting along mainstem shorelines in the Kenai River. Low stream-side velocities in the Kenai River allow for exploitation of widely available contiguous rearing habitats by juvenile chinook salmon and extensive movements within the drainage. This results in the ephemeral use of specific habitat sites and dramatic changes in the seasonal distribution and relative abundance of juvenile chinook salmon.

Habitat permit guidelines based on habitat types or river reach may not adequately protect rearing chinook salmon from stream bank developments in the Kenai River. The addition of instream or riparian cover to bank stabilization structures can mitigate the adverse effects of altered depth, velocity, or substrate characteristics. Existing groins, extending from the shoreline, disrupt contiguous rearing habitats and represent the most significant man-made obstruction to the passage of juvenile salmonids in the mainstem Kenai River.

KEY WORDS: Kenai River, juvenile fish, chinook salmon, overwintering, habitat preference, migration, movement, coded-wire tag, seasonal distribution, habitat management.

INTRODUCTION

The Kenai River (Figure 1), located in southcentral Alaska on the Kenai Peninsula, has developed into one of the most intensively used river systems in Alaska. Abundant Pacific salmon *Oncorhynchus* spp. runs, road accessibility, and the proximity of the Kenai River to major population centers have contributed to a dramatic increase in private, recreational, and commercial developments within, and adjacent to, the Kenai River. During 1987, anglers expended approximately 290,000 angler-days of effort in the Kenai River making this the largest freshwater fishery in Alaska (Mills 1988).

Private, recreational, and commercial developments adjacent to, and within the Kenai River, may represent the greatest threat to the long-term productivity of the drainage. The Alaska Department of Fish and Game (ADF&G) is responsible for addressing public concern about the biological impacts to the river resulting from increased development, as well as establishing a policy for discharging its permitting authority covering a wide variety of activities within the drainage.

Along the mainstem Kenai River below Skilak Lake, approximately 66% of the adjacent river land is in private ownership, 15% is owned by the cities of Soldotna and Kenai or the Kenai Peninsula Borough, 15% is in State ownership, and 4% is in Federal ownership (Alaska Department of Natural Resources 1986). Developments adjacent to the river include businesses, permanent and seasonal residences, and recreational facilities; while instream developments include boat docks, launching facilities, canals, boat basins, groins, and several types of revetments. Road construction, draining and filling of wetlands, and the removal of instream debris and riparian vegetation have accompanied the development of the Kenai River. Public concern that uncontrolled development of the Kenai River will increase rates of erosion and degrade habitats required to support fish resources prompted the formation of the Kenai River Special Management Area (KRSMA) by the Alaska State Legislature in 1984. The KRSMA encompasses all State owned lands along the river and is managed by the Alaska Department of Natural Resources (ADNR). As a result of KRSMA legislation, the recommendations of a special advisory board, and a series of public meetings held throughout the region, the ADNR adopted the Kenai River Comprehensive Management Plan in 1986. The plan addresses development concerns of private land owners and public agencies, and identifies goals and objectives for future use of the river. It recommended land-use permit guidelines that were based on river reach and habitat type. This implies that specific habitat types or river reaches are more important to juvenile fish than others, and that a differential approach to permitting, based on these two criteria, may be the best solution for managing development of the shoreline. Implementation of the plan is contingent upon the cooperative efforts of agencies, local government, and private landowners; however, a major impediment to the entire process has been a lack of fundamental resource information.

To address this, and related informational needs, the ADF&G has entered into a multi-year cooperative effort with the U.S. Soil Conservation Service, the U.S. Fish and Wildlife Service, ADNR, the U.S. Corps of Engineers, the Kenai Peninsula Borough, and the U.S. Geological Survey. The primary focus of the
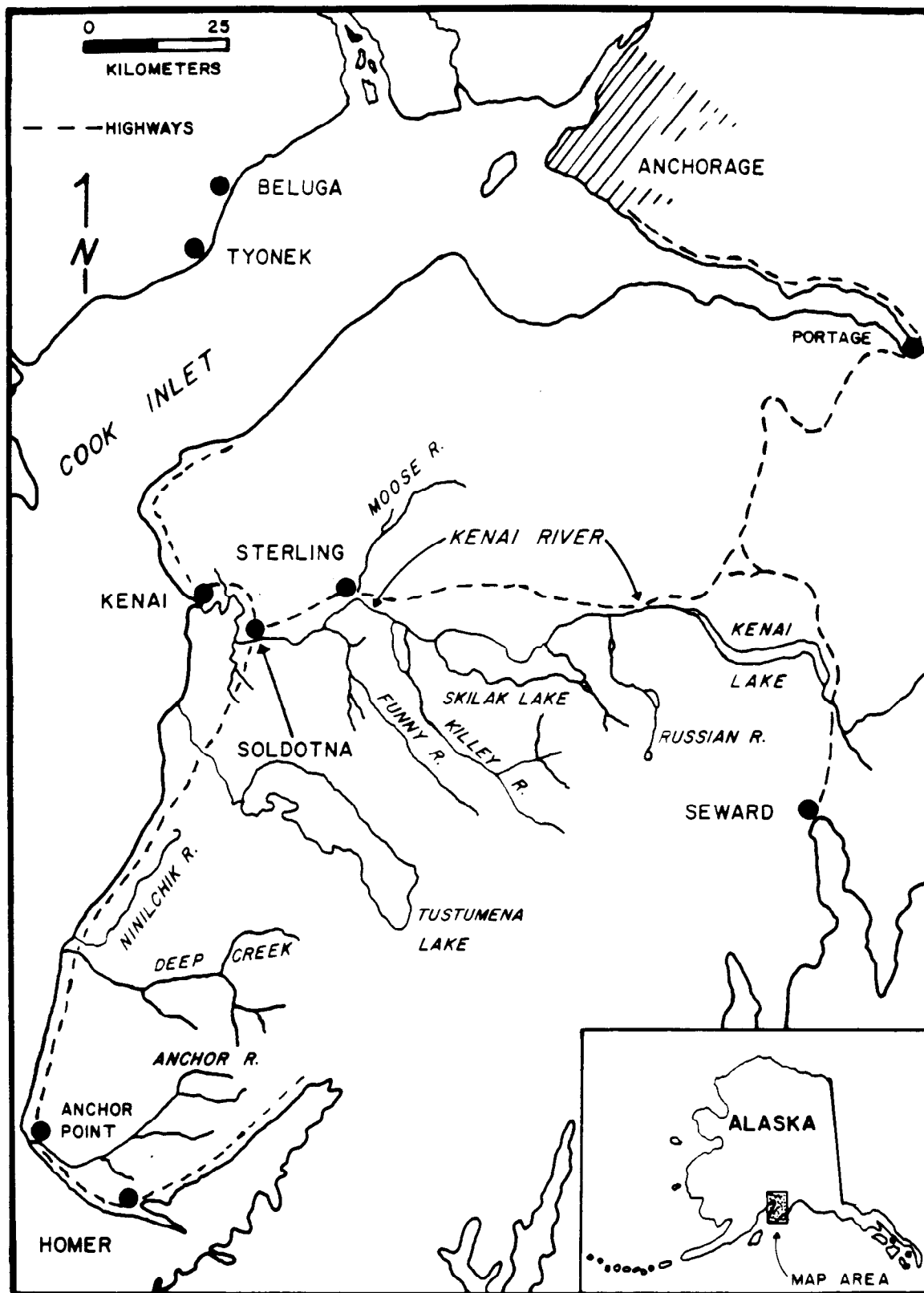
Figure 1. Map of the Kenai Peninsula showing the Kenai River Basin.

ADF&G effort has been to obtain low-level, color infrared photography of the river corridor and to initiate sampling for baseline habitat and biological data necessary to formulate development policies for the Kenai River (Estes and Kuntz 1986, Litchfield and Flagg 1986, Bendock and Bingham 1988a and b). Burger et al. (1983) described juvenile salmon distribution, catch rates, and habitat utilization in the lower 72 km (45 mi) of the Kenai River, while Elliott and Finn (1984) investigated juvenile fish use of several tributaries to the lower river.

The goal of this project is to obtain seasonal, baseline fisheries and habitat data for establishing a rationale and policy to address development activities in the Kenai River drainage. Bendock and Bingham (1988a) described the feasibility of estimating winter distribution and habitat preferences for juvenile salmonids in the mainstem Kenai River using three different sampling gears. Potential sources of variation in habitat preference were examined using multivariate analysis of covariance of juvenile salmon catches as affected by cover, substrate type, depth, and velocity. Habitat diversity in the mainstem Kenai River is substantially reduced during winter months. Juvenile chinook salmon *Oncorhynchus tshawytscha* occupied a variety of winter habitat types in the mainstem from Cook Inlet to Skilak Lake but exhibited a marked preference for overwintering in interstitial spaces provided by large, near-shore substrates. Subsequent sampling (Bendock and Bingham 1988b) confirmed this behavior but failed to show significant interactions between the winter density of chinook salmon and water depth, velocity, or macrohabitat conditions. The presence of instream or riparian cover had the greatest influence on summer catch rates of juvenile chinook salmon. Macrohabitat did not significantly influence either summer or winter catch rates which implied that permit guidelines based on habitat type or river reach may not achieve the desired goal of protecting chinook salmon habitat from stream bank developments in the Kenai River. Results of our studies suggested that suitable summer rearing habitat is widely available along the margins of the Kenai River and occupied by chinook salmon from tidewater up to Skilak Lake.

Burger et al. (1985) found that most mainstem spawning by chinook salmon in the Kenai River occurred in only two areas (river km 16-34 and river km 64-80). Estes and Kuntz (1986) suggested that the population of rearing chinook salmon fry at a particular area in the river appears relatively open rather than closed; while Litchfield and Flagg (1986) documented both upstream and downstream movements by juvenile chinook salmon in the Kenai River. Our studies showed abrupt and significant declines in the relative abundance of juvenile chinook salmon between summer and winter seasons. These data suggest that mobility is the mechanism that allows sub-yearling chinook salmon to disperse from relatively limited areas of emergence and exploit widely available summer rearing habitats as well as overwintering habitats.

This report summarizes research conducted in 1988 on the mobility of sub-yearling chinook salmon in the mainstem Kenai River. Conclusions regarding the distribution, seasonal abundance, and habitat preferences of juvenile chinook salmon are presented and the implications of these findings on habitat permitting for the Kenai River are discussed. Common names, scientific

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names, and abbreviations for fish species inhabiting the Kenai River are shown in Appendix Table 1.

The specific objective for the 1988 field season was to test the hypothesis that age 0 chinook salmon migrate upstream from the lower Kenai River (river km 21.6 to 26.4) to overwinter in Skilak Lake (river km 80) during the fall. Sub-objectives associated with testing this hypothesis were to:

a. estimate the proportion of marked chinook salmon in the lower Kenai River tagging reach after all marked fish have been released; and to

b. estimate the number of lower-river-origin age 0 chinook salmon captured in fyke traps near the outlet of Skilak Lake.

METHODS

To accomplish our objectives, we trapped, marked, and released age 0 chinook salmon in the lower Kenai River. Minnow traps were selected as the most efficient gear for capturing juvenile chinook salmon in mainstem habitats during the open water season (Bendock and Bingham 1988b). I estimated the proportion of marked fish at-large within the tagging reach and examined minnow and fyke trap catches for marked chinook salmon below, within, and above the tagging reach and near the outlet of Skilak Lake (56 river km upstream from the tagging reach) (Figure 2). The following five species and species categories were used to record the catch composition in all phases of the study: chinook salmon, sockeye salmon *Oncorhynchus nerka*, coho salmon *Oncorhynchus kisutch*, other salmonids, and other species.

Rudimentary data summaries, frequencies, and plots of catches by species categories, location, or occasion were produced by utilizing the database and reporting facilities of the REFLEX (Borland 1985) microcomputer program. Additional analyses were conducted using the Statistical Analysis System (SAS 1985a and b) program. All statistical tests were conducted at the 90% (α = 0.10) significance level unless otherwise noted.

Coded-Wire Tag Deployment

Minnow traps measuring 48 cm x 20 cm x 0.6 cm and baited with brine-cured salmon roe were used to capture age 0 chinook salmon between river kilometers 21.6 and 26.3 during the period 8 July to 26 August 1988. Twelve baited traps were typically deployed along 61 m of shoreline for approximately 20 minutes each. The resulting catch was placed into 5 gallon plastic buckets and transported by river boat to a centrally located (river km 24.5) tagging facility. Fish were then transferred to 30 gallon plastic tubs that were equipped with a continual supply of circulating river water. Chinook salmon were anesthetized with tricaine methanesulfonate (MS-222), marked by removing the adipose fin, and injected with a 1.0 mm coded-wire tag using a Northwest Marine Technologies Inc. (NMT) tag injector. Tagged fish were passed head-first through a NMT quality control device that magnetized and confirmed the presence of the tag. They were then allowed to recover in a
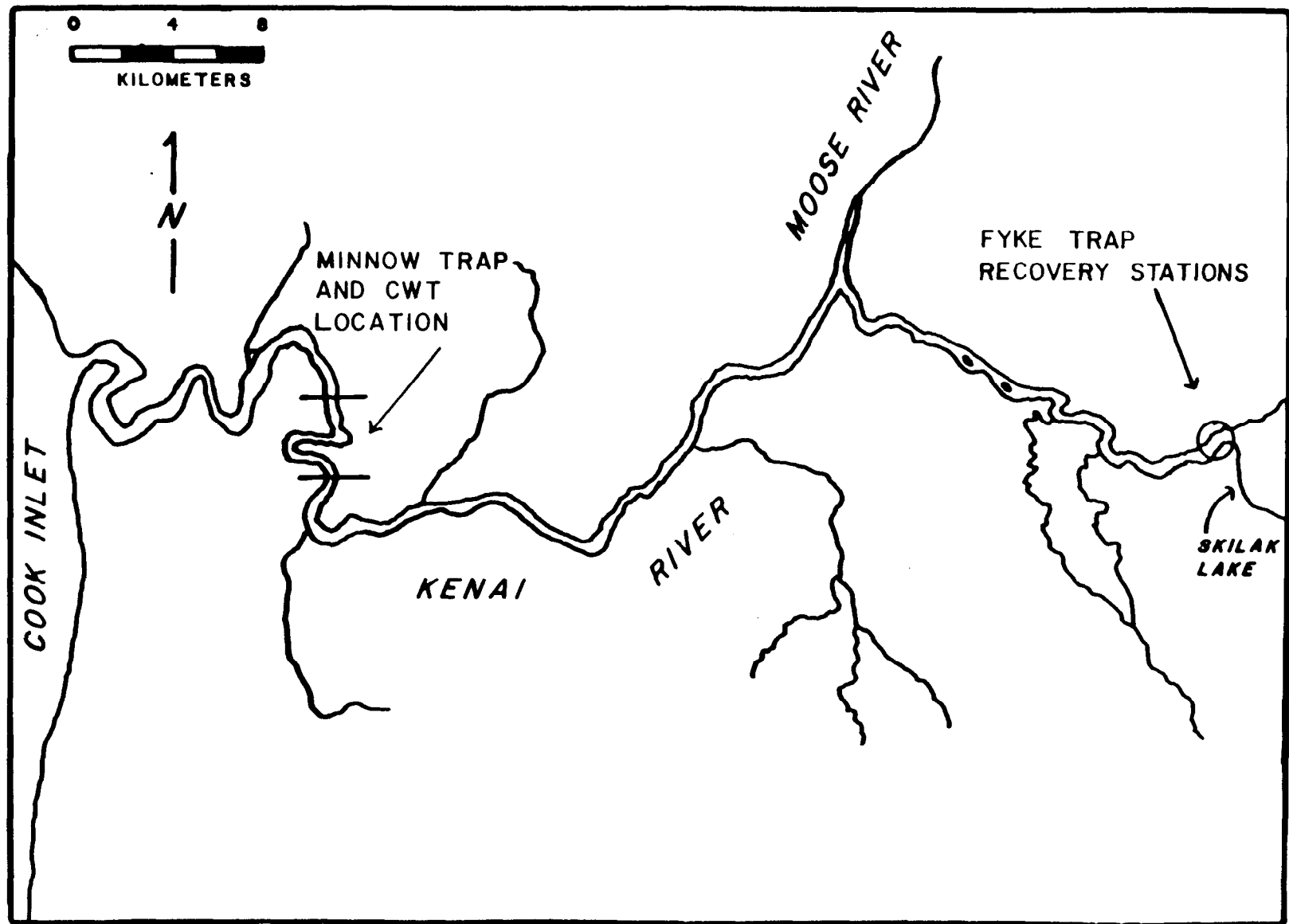
Figure 2. Map of the Kenai River from Cook Inlet to Skilak Lake showing the minnow trap tagging and fyke trap recovery locations.

holding tank for approximately 1 hour and released at their point of capture.
The same binary code was used to identify all of the coded-wire tags deployed
in this study. Short-term handling mortality and tag retention were
estimated using observed frequencies in a daily sample of 50 fish that were
held overnight and passed again through the quality control device. We
trapped fish along both shorelines beginning at the downstream end of the
tagging reach and systematically advanced upstream when marked fish were
returned to a site. Species other than chinook salmon were identified,
counted, recorded, and released.

Tag Recovery Using Minnow Traps

The proportion of marked chinook salmon in the tagging reach was estimated
from minnow trap catches during 17 to 27 September 1988. Trap sites were
selected randomly within the 4.8 km tagging reach by dividing both shorelines
into increments, each 61 m in length and representing a potential sample
site. Each increment was numbered and a set of random numbers between 1 and
177 (the total number of available sites) was used to select each sample
site. Each site was fished for 30 minutes with 12 baited traps. The catch
at each site was identified, counted, examined for marks (excised adipose
fins), recorded, and released. Trapping continued within the tagging area
until 20,000 age 0 chinook salmon were examined for marks.

To establish the sample size requirement (20,000 fish) for the proportion
estimate that would give the desired level of precision (d), we used expected
values for the number of chinook salmon that were tagged and examined for
marks using Cochran (1977):

$$d = (z^2(p)(1-p) / n)^{\frac{1}{2}} \qquad [1]$$

where:

p = expected proportion (=0.04),

z = tabled z statistic (=1.68 for α = 0.10), and

n = expected sample size (=20,000).

This expected precision in estimating the proportion of marked fish in the
lower river tagging reach would result in an expected precision for estimat-
ing the number of lower-river-origin chinook salmon in the fyke trap catch of
approximately ±6%.

An additional 243,307 trap-minutes of effort were expended above and below
the tagging reach and in Skilak Lake during 27 September to 7 November.
Sample sites were chosen subjectively based on their proximity to highway
access. The number of traps at these sites ranged from 3 to 18, and soak
times ranged from 15 to 4,290 minutes. Catches were identified, counted,
examined for marks, recorded, and released.

Tag Recovery Using Fyke Traps

Fyke traps (Figure 3) located near the outlet of Skilak Lake were the principle means by which chinook salmon were captured and examined for marks. Each trap was constructed from 1.3 cm concrete reinforcement rod and measured 1.2 m in width and height by 1.5 m in depth. Two entrance funnels and a center partition allowed us to segregate fish that encountered the traps from both upstream and downstream directions. Traps were covered with 0.6 cm hardware cloth and attached to shore with a 1.2 m X 18.2 m X 0.6 cm knotless nylon beach seine. Two traps were fished at 5 locations (Figure 4) during the 14 September to 7 November time period. Site 2 was fished continuously during the sample period while the remaining trap was moved between the other locations. The traps fished for 7 days each week but catches were only examined on weekdays. Catches from the upstream and downstream holding areas were treated separately. Fish were removed from the traps with dip-nets, placed in 5 gallon plastic buckets, and transported by boat to a tent facility located at river km 79.2 where they were held in 30 gallon plastic tubs supplied with circulating river water. All fish were anesthetized with MS-222 and were identified, counted, and recorded. Chinook salmon were examined for marks (excised adipose fins). Unmarked chinook salmon and all other fish were released in the river adjacent to the tent facility. Marked chinook salmon were measured to the nearest millimeter in fork length, retained, and frozen for later tag confirmation. Salmon catches were batch-marked using Bismark Brown dye on 21 September, 29 September, and 3 October to establish if individual fish were being recaptured in subsequent sampling events.

Estimating the Proportion of Marked Chinook Salmon in the Tagging Reach

The proportion of marked age 0 chinook salmon in the lower river tagging reach (river km 21.6 to 26.3) was estimated using observed frequencies of the marked fish in the recapture samples. A 90% confidence interval (CI) for the estimate was calculated using Cochran (1977):

$$90\% \ CI = \hat{p} \pm (\ [(1.68) \ (\ \hat{p}(1-\hat{p}) \ / \ (n_2-1))^{\frac{1}{2}} \ ] + (1 \ / \ 2n_{t2}) \ ) \qquad [2]$$

where:

$\hat{p}$ = $n_{t2} \ / \ n_2$, estimated proportion of marked age 0 chinook salmon to all age 0 chinook salmon,

n_{t2} = number of marked age 0 chinook salmon in the recapture sample, and

n_2 = total number of age 0 chinook salmon in the recapture sample.

Estimating the Contribution of Lower-River-Origin Chinook Salmon to the Upper River Fyke Trap Catch

Estimates of the marked proportion in the tagging reach were combined with the observed number of marked fish caught in the fyke traps to estimate the

WINGS & CENTER LEAD CONSTRUCTED
WITH 0.6cm KNOTLESS NYLON MESH

WING LEAD

CURRENT

1.2 m

CENTER LEAD (TO SHORE)

WING LEAD

HOLDING AREAS

REBAR FRAME – SIDES &
BOTTOM COVERED WITH
0.6cm HARDWARE CLOTH

Figure 3. Schematic example of the fyke traps used to capture juvenile fish near the outlet of Skilak Lake.
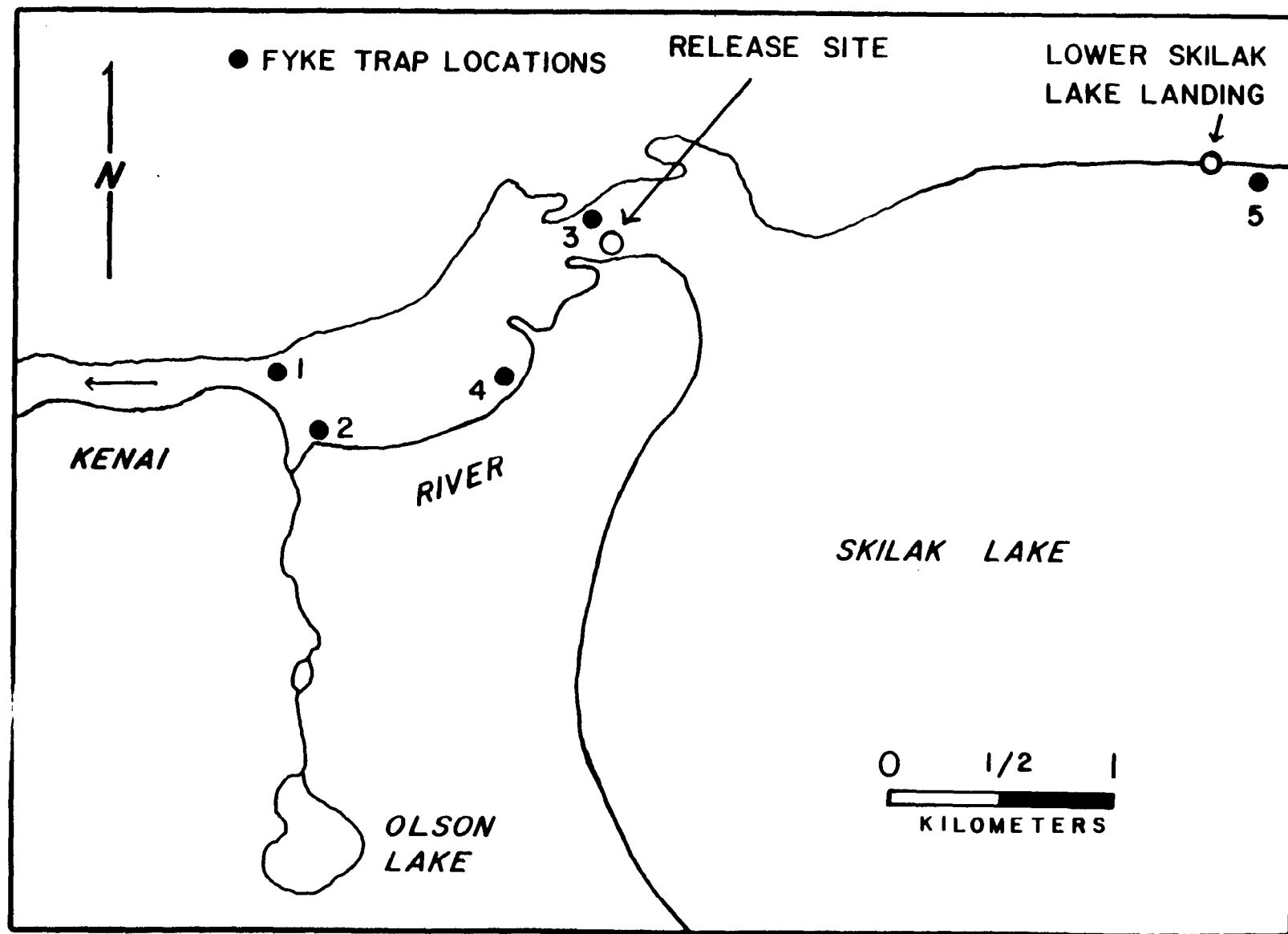
Figure 4. Map of the Kenai River near the outlet of Skilak Lake showing the five fyke trap
locations and juvenile fish release site.

number of lower-river-origin chinook salmon in the fyke trap catch. Specifically, a modified version of equation 10 from Clark and Bernard (1987) was used to estimate the contribution:

$$n_1 = m_c \div \hat{p}$$ [3]

where:

n_1 = the estimated contribution,

m_c = the number of marked fish caught in the fyke traps, and

$\hat{p}$ = the estimated proportion of marked fish in the tagging reach as estimated above.

The modification to equation 10 from Clark and Bernard (1987) involved cancellation due to assumed equivalencies in the additional terms in the original equation (i.e., $m_1 = m_2$, $a_1 = a_2$, $N = n_2$, using the notation as in Clark and Bernard 1987).

The procedures for obtaining a variance or standard error estimate of the contribution estimate as outlined in Clark and Bernard (1987) were not followed due to our having to estimate p-hat (which is a constant term, theta, in Clark and Bernard 1987). Accordingly, a bootstrap procedure was used to obtain the standard error of this estimate (Efron and Gong 1983). The procedure followed involved randomly sampling with replacement a total of n_2 fish from the original n_2 fish sampled for estimating p-hat which were either marked or unmarked. This sample was then used to estimate one value of p-hat. Then we randomly sampled with replacement a total equal to the number of chinook salmon recovered in the fyke trap sampling from the original fyke trapped fish which were either marked or unmarked. This sample was used to obtain one value of m_c. Then the p-hat and m_c values were combined to obtain one value of n_1. The preceding process describes one bootstrap replicate. This process was repeated a total of 400 times. The standard deviation of the different values of n_1 from the 400 replicates provided our estimated standard error for n_1 as obtained above. An approximate 90% confidence interval was then obtained as follows:

$$n_1 \pm 1.645 * se^*(n_1)$$ [4]

where:

$se^*(n_1)$ = bootstrap standard error estimate.

RESULTS

Coded-Wire Tag Deployment

A total of 99,600 fish was captured in 87,180 trap-minutes of effort in a 4.8 km (3 mi) reach of the lower Kenai River between 8 July and 26 August 1988. Age 0 chinook salmon accounted for 95% of the catch followed by coho salmon (2.1%). Of 94,585 chinook salmon that were captured, 90,105 were injected with coded-wire tags and returned to the river, while 2,911 (3.2%) represented recaptured fish. A total of 1,569 chinook salmon were rejected for tagging due to logistical constraints, physical deformities, or injuries resulting from handling or transport. The mean catch-per-unit-effort (CPUE) for chinook salmon was 1.085 fish/trap-minute. Tagging was conducted at a mean rate of 557 fish/hr which resulted in a mean tag deployment rate of 2,650 tagged chinook salmon per day. The short-term mortality and tag retention rates for chinook salmon were 0 and 99.6%, respectively.

Proportion of Marked Chinook Salmon in the Tagging Reach

Minnow traps were randomly deployed in the tagging reach (river km 21.6 to 26.3) following a 2 to 9 week hiatus from the time the first and last tagged chinook salmon were released, respectively. This sampling event occurred from 14 to 27 September. An effort of 9,258 trap-minutes yielded a catch of 20,401 chinook salmon of which 1,598 were marked and 18,803 were unmarked. The proportion of marked chinook salmon in the sample is 0.07833 (90% CI ± 0.00243). Concurrent minnow and fyke trap sampling in other river reaches indicated that by the time we initiated sampling during this event (14 September), marked chinook had dispersed throughout the mainstem from the confluence with Beaver Creek (river km 17.4) to Skilak Lake (river km 80). Hence, the ratio estimate was most likely negatively biased, since fish moving into the tagging area from adjacent river reaches would have resulted in increased numbers of unmarked fish.

Coded-Wire Tag Recovery

Coded-wire tagged chinook salmon were recovered by examining minnow and fyke trap catches for marked fish. Minnow trapping was conducted between river kilometer 17.4 and 83.0 while fyke traps were stationed near the outlet of Skilak Lake (river km 77.6 to 80.0). Both gears were deployed for a short time in Skilak Lake (river km 84.4)

Minnow Trap Sampling:

A total of 3,654 chinook salmon were examined for marks in minnow trap catches between river km 17.4 and 83.0 during 27 September to 7 November (Table 1). Twenty-eight of these fish had marks. Most of the marked fish (86%) were recovered between river kilometers 20 and 40 during late September to mid-October. Marked fish were recovered below and above the tagging reach; however, no tagged fish were recovered upstream from river km 40 in the minnow trap catches. One marked fish was recovered at river km 17.4 representing a 6.6 km downstream movement from the tagging reach, while three marked fish were recovered at river km 39.4, representing a 15.4 km upstream

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Table 1. Minnow trap effort, chinook salmon catch, and numbers of
marked fish recovered by 20 kilometer intervals in the
mainstem Kenai River, 1988.

Kilometer	Effort (trap-min.)	Chinook Salmon Catch	Numbers of Marked fish	Date(s)
0-19	788	644	4	27,28 Sep.
20-39[1]	3,435	1,462	24	28,29 Sep.& 7,13,14 Oct.
40-59	956	40	0	4,7,13 Oct.
60-79	186,631	1,429	0	7, 13 Oct. thru 4 Nov.
Skilak L.	57,780	79	0	2-7 Nov.
All	249,500	3,654	28	27 Sep. to 7 Nov.

[1] Contains the tagging reach (river km 21.6 to 26.3).

movement from the tagging reach. The overall proportion of marked fish from this sample was 0.008. Chinook salmon catch rates using baited minnow traps declined significantly between summer and fall. The CPUE for October to November catches was 0.015 compared to 1.192 for July through September catches. Thus, we were unable to capture and examine large numbers of fish for marks after the month of September using baited minnow traps.

Fyke Trap Sampling:

Two fyke traps stationed near the outlet of Skilak Lake captured a total of 94,765 fish between 14 September and 7 November. A total of 20,681 chinook salmon was captured and 22 of these fish had marks. An additional marked fish was recovered while dumping excess fish from a trap and was not used in the following analysis. The recovery of 22 marked fish in the fyke trap catch indicates that an estimated 281 (i.e., $22 \div 0.07833$) lower-river-origin chinook salmon were captured near the outlet of Skilak Lake. The approximate 90% CI limits about this estimate were 175 to 386 fish obtained by the bootstrap method (with $se^*(n_1) = 64.0244$, which is comparable with a standard error estimate of 57.4876 using the procedures outlined in Clark and Bernard 1987). Marked chinook salmon, recovered between 15 September and 10 October, were captured in proportion to unmarked chinook salmon at the fyke trap stations (Figure 5). This suggests that marked fish did not migrate to Skilak Lake in a discrete group but had mixed with unmarked fish in the population. These fish migrated upstream approximately 56 km during a 10 to 14 week period from the time the first tagged fish were released in the lower river.

Catch Composition and Chinook Salmon Relative Abundance

Chinook salmon accounted for 95%, 94%, and 38% of the tagging, marked to unmarked ratio, and tag recovery efforts, respectively, using minnow traps (Figure 6). As the relative abundance of chinook salmon (measured by the change in catch component) declined, the variability of catch rates increased. Mean catch rates for July and August were significantly different than those for September and October (Table 2). The less variable catches in July and August characterize a uniform distribution for chinook salmon among sample sites, while highly variable catches beginning in September suggested a clustered distribution. Although sample sites were not classified by habitat categories in this study, field observations indicated that the highest chinook salmon catches in September occurred in areas of dense cover and at public access sites where fish cleaning facilities were still in use. By October, baited minnow traps were not effective for capturing chinook salmon, and coho salmon comprised the largest (64%) component of the catch.

Chinook salmon represented 22% of the combined fyke trap catches. Chinook salmon catch proportions were significantly different among trap locations and ranged from 10% at site 4 to 38% at site 2 (Figure 7). The overall chinook salmon CPUE was 211 fish/trap-day (f/t-d) which was intermediate between coho salmon (472 f/t-d) and sockeye salmon (86 f/t-d). Chinook salmon daily catch rates declined throughout the fyke trap sample period from a high of 959 f/t-d during the first week of sampling to a low of 9 f/t-d during the final week (Figure 8). Ninety-one percent of the chinook salmon
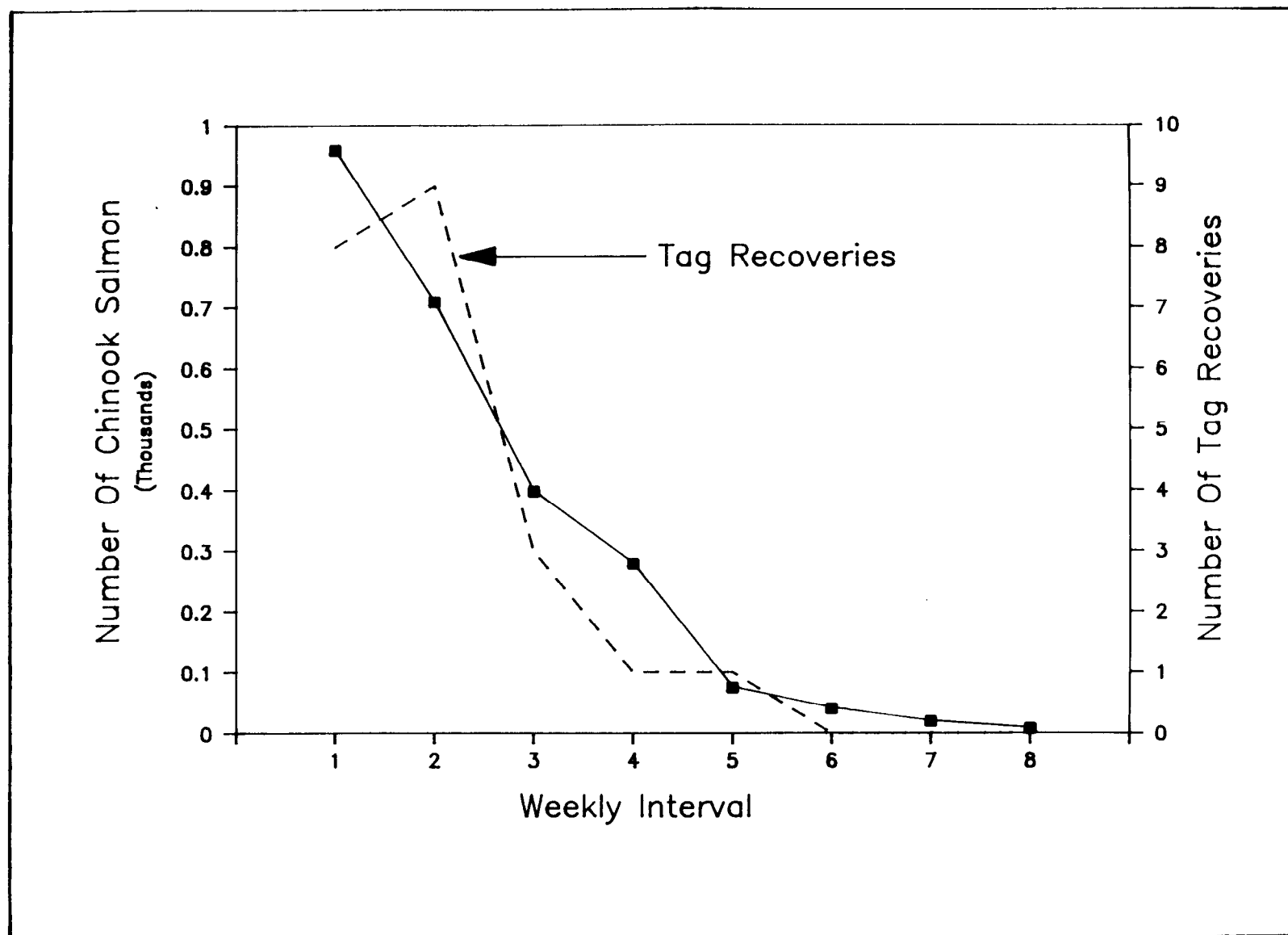
Figure 5.   Catch of chinook salmon and coded-wire tag recoveries by weekly intervals in fyke traps near the outlet of Skilak Lake, 1988.

Minnow Trap Catch Composition

Tag Deployment
7/8 – 8/26
(n = 99,600)
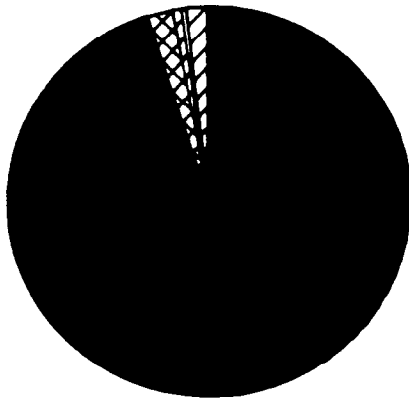
Tag Ratio
9/14 – 9/27
(n = 21,819)
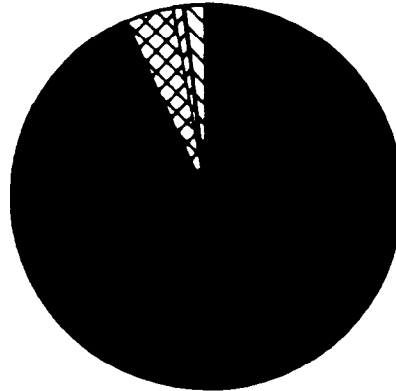
Tag Recovery
9/27 – 11/4
(n = 8,332)

Skilak Lake
11/2 – 11/7
(n = 155)

■ Chinook Salmon   ▨ Coho Salmon   ▧ Sockeye Salmon

☐ Other Salmonids   ▩ Other Species
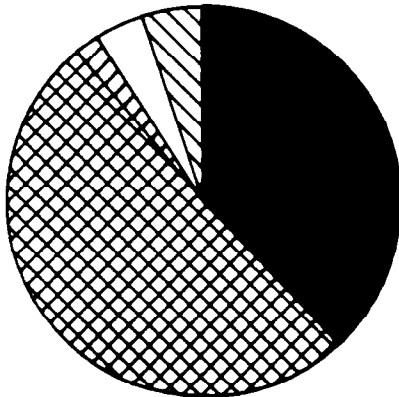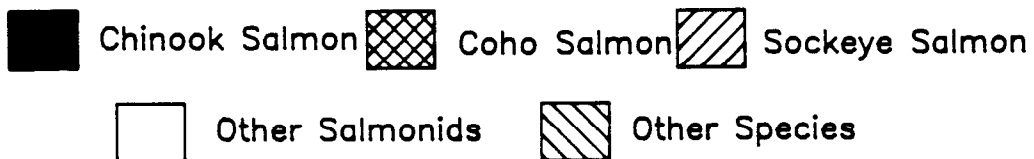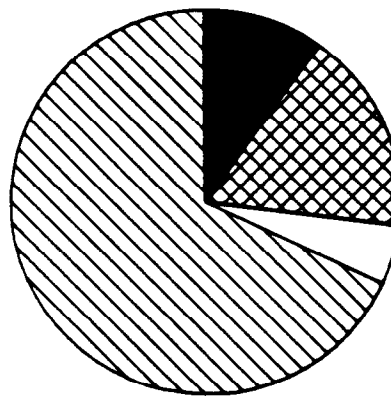
Figure 6. Minnow trap catch composition during four study phases
in the Kenai River and Skilak Lake, 1988.

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Table 2. Minnow trap catch statistics for age 0 chinook salmon captured in the mainstem Kenai River during four monthly intervals in 1988.

Month	n	Effort (trap-min)	No. of Chinook	Catch Rate (fish/trap-min)					
				Min.	Max.	Mean	STD	SE	Relative Precision [1]
July	13	26,722	28,257	0.608	2.901	1.207	0.671	0.186	25.3%
Aug.	18	60,120	66,328	0.649	2.975	1.222	0.560	0.132	17.8%
Sept.	40	9,298	20,401	0.006	6.933	2.172	1.850	0.293	22.2%
Oct.	19	133,683	1,049	0.002	0.030	0.009	0.007	0.002	36.6%

[1] $a = 0.10$.
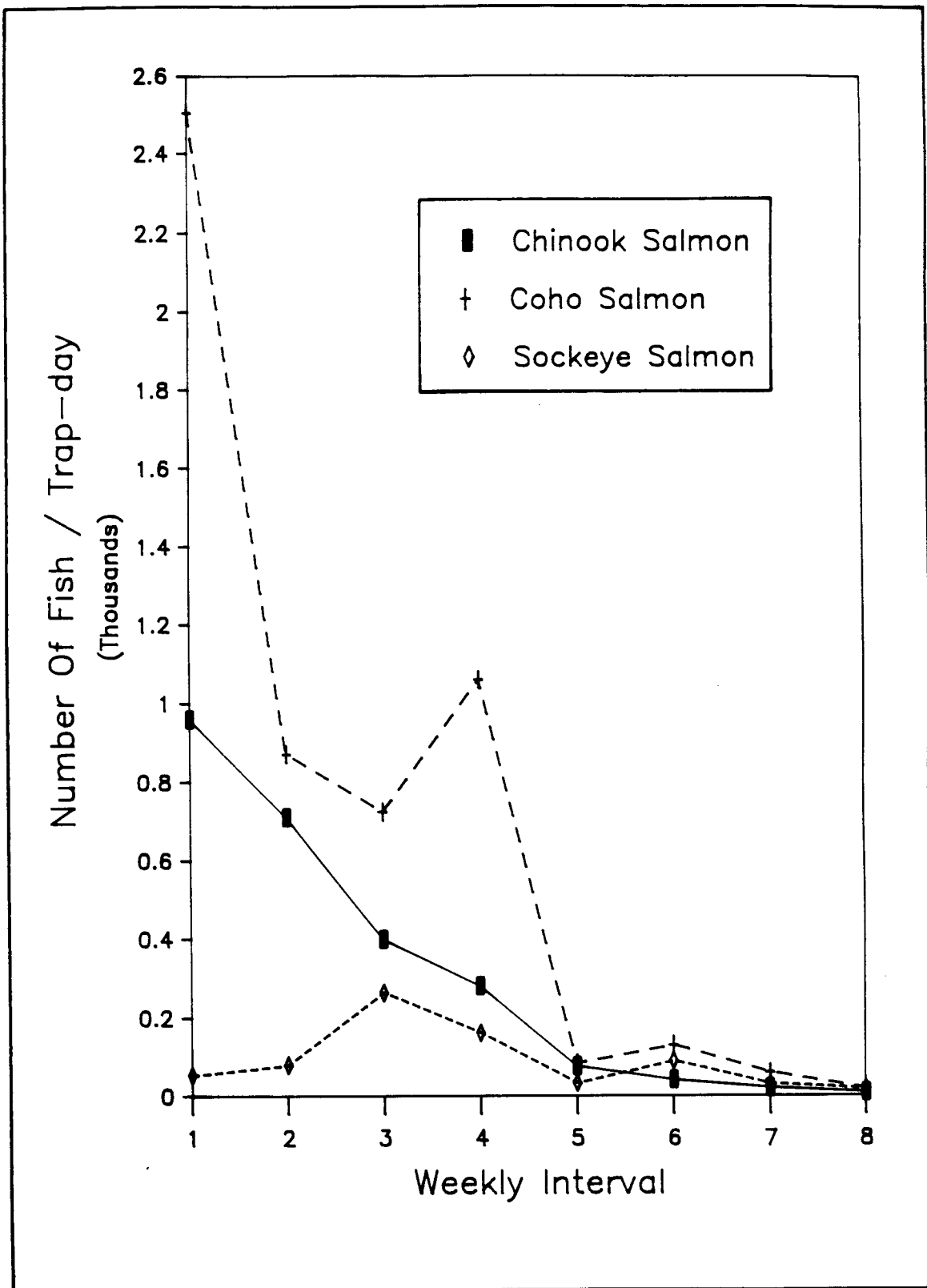
Figure 8.   Juvenile salmon catch rates by weekly intervals for fyke
traps located between river km 77.6 and 80.0 in the mainstem
Kenai River, 1988.

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Fyke Trap Catch Composition

Figure 7. Fyke trap catch composition at five locations in the
Kenai River and Skilak Lake, 1988.

catch was obtained during the first half of the sample period. Similar patterns of declining chinook salmon abundance were observed at the same location for fyke trap catches during 1987 and 1988 (Figure 9). This pattern of abundance suggests that use of this area by chinook salmon is ephemeral and that our sampling was initiated after the peak of abundance. Similar patterns of abundance were observed for coho and sockeye salmon. Experiments using Bismark Brown dy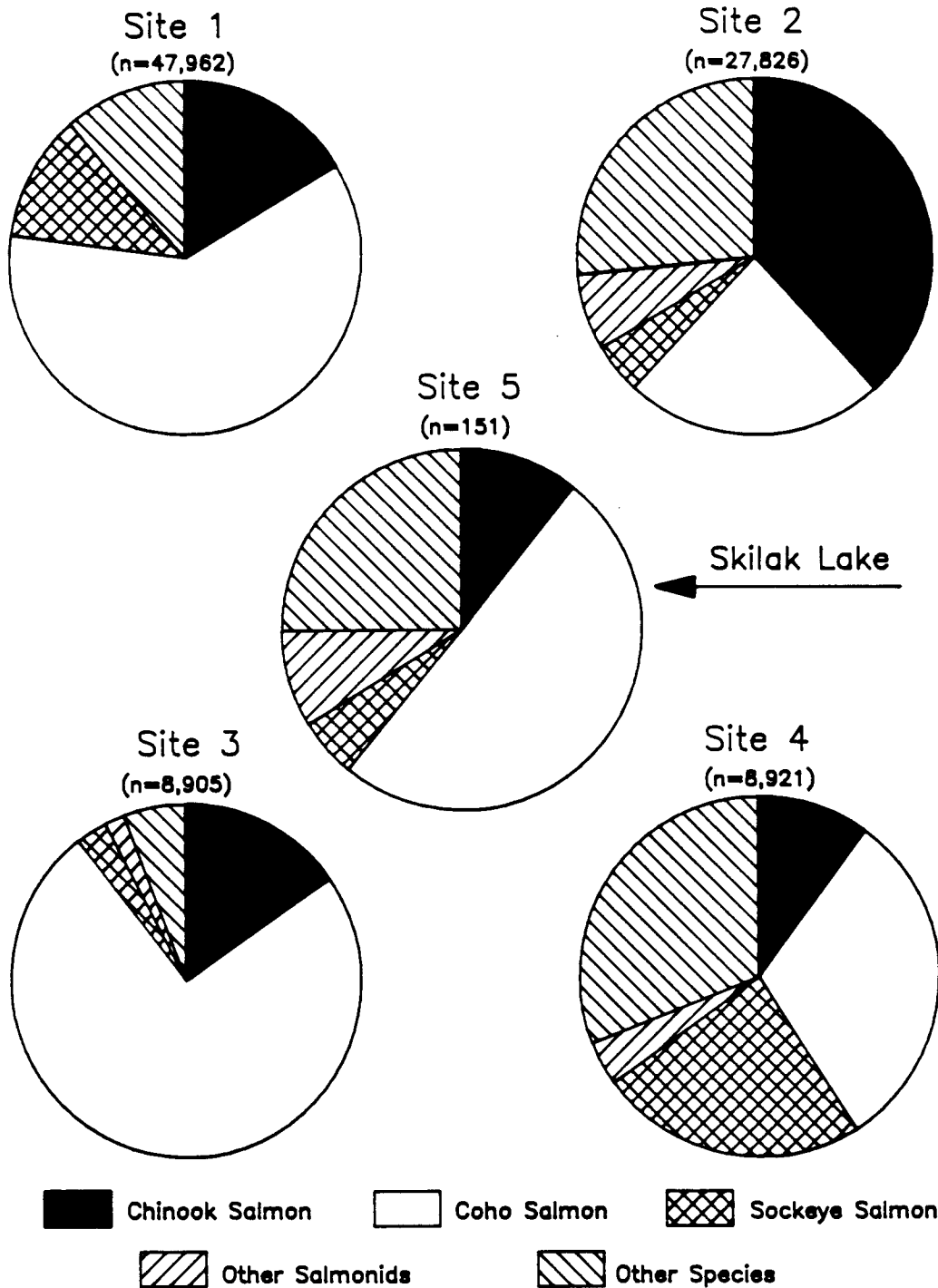e indicated that large numbers of salmon were not re-entering the fyke traps following handling and release at river km 79.2. The recapture rate of dyed chinook salmon ranged from 0 to 1.4% and the rate for coho salmon was 0 to 1.0% following 1 day and 3 day trials. I interpret the fall declines in minnow trap and fyke trap catch rates to be the result of age 0 chinook salmon movement out of mainstem habitats and into Skilak Lake for overwintering. The recovery of marked fish in the fyke trap catches confirmed that age 0 chinook salmon are capable of extensive upstream movements within the drainage.

Chinook Salmon Directional Movements at Fyke Trap Stations

Fish that entered the fyke traps from both upstream and downstream directions were treated separately to establish the directions of movement along the shoreline. The directional components of chinook salmon catches were analyzed by weekly intervals (Figure 10). Chinook salmon that entered traps while moving downstream accounted for 58% of the catch and those moving upstream represented 42%. The weekly proportions of upstream catch components varied from 30% to 62% and averaged 49%. A contingency table analysis of these data indicated that weekly chinook salmon directional catch components were not independent of sampling occasion ($\chi^2 = 666.825$, df = 7, P < 0.005). Tagged fish (having a known downstream origin) were recovered at the fyke traps in similar directional frequencies as untagged fish. Fifty-nine percent of the tag recoveries entered the traps while moving downstream and 41% entered while moving upstream. I conclude from these data that entry patterns of fish at fyke trap stations reflect local movements along the shoreline, rather than a broader pattern of migrational direction.

Length Frequencies of Tagged Chinook Salmon

Fork lengths were obtained from the first 334 tagged chinook salmon that were recovered using minnow traps from river km 21.6 to 26.4 during 19 to 20 September; and from all tagged fish (n=23) recovered in fyke traps from river km 77.6 to 80.0 during 15 September to 10 October. Fish recovered in the upper river sample were significantly larger in mean fork length than those from the lower river sample. Fork lengths of tagged fish captured in the lower river ranged from 52 mm to 82 mm and averaged 63.4 mm (90% CI ± 0.533); while those from the upper river ranged from 66 mm to 96 mm and averaged 79.7 mm (90% CI ± 5.633). Length frequency distributions for both samples are shown in Figure 11. These data suggest that the ability of chinook salmon to undertake upstream migrations within the mainstem Kenai River may be related to length.

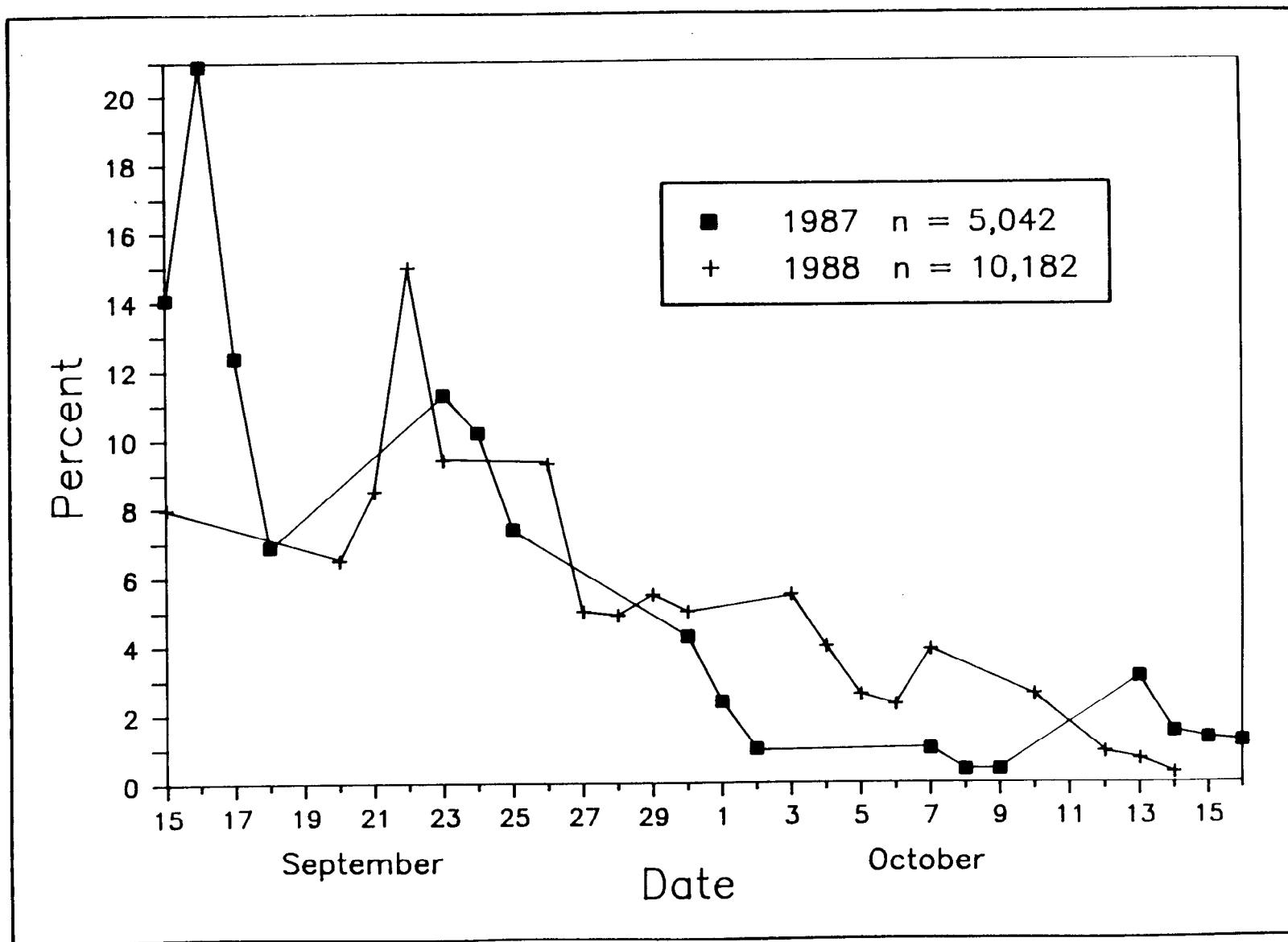Figure 9. Fyke trap catch frequencies for chinook salmon during 1987 and 1988 at river km 77.6
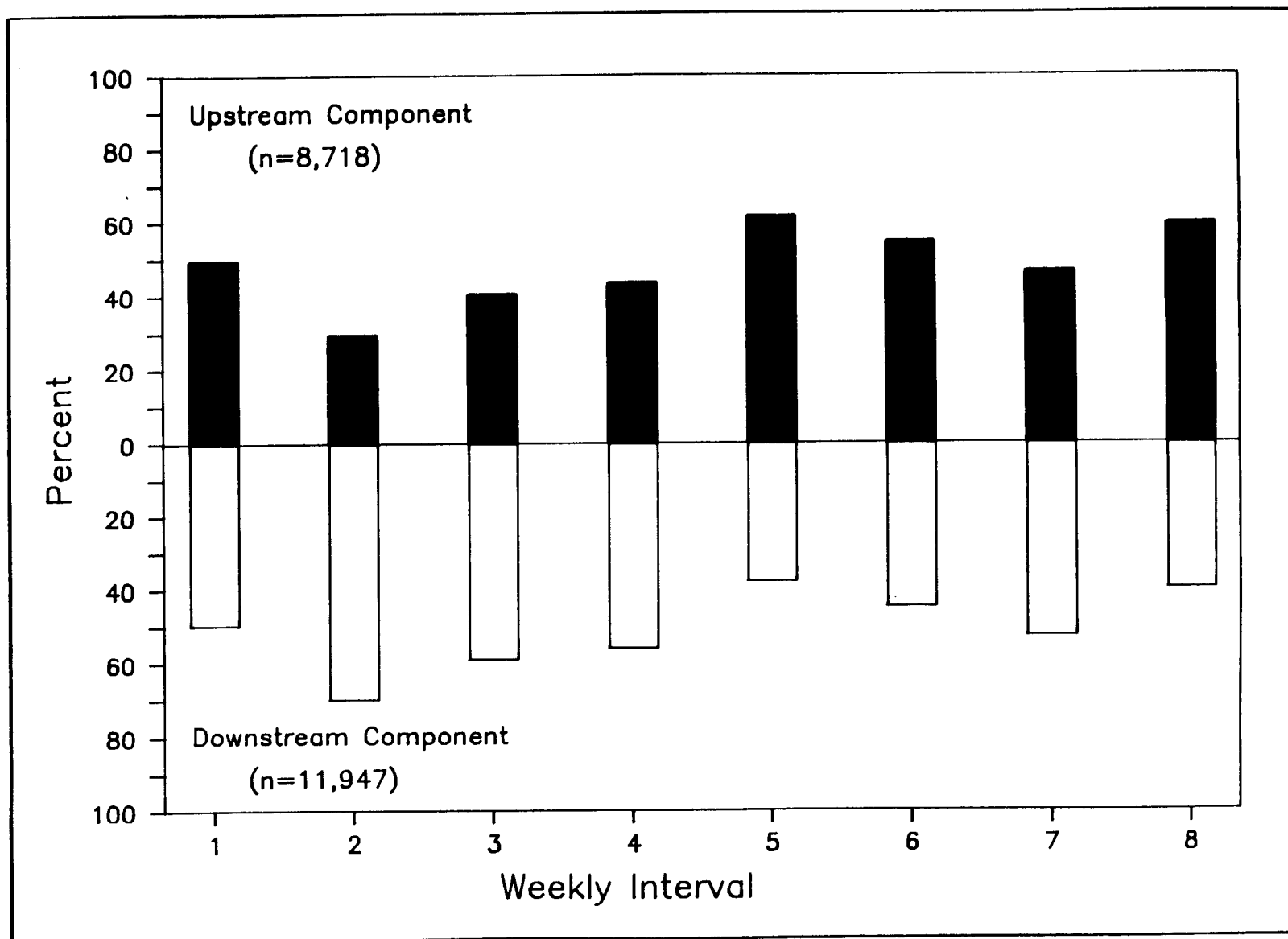in the Kenai River.

Figure 10. Directional components of the chinook salmon catch by weekly intervals for fyke traps in the Kenai River, 1988.
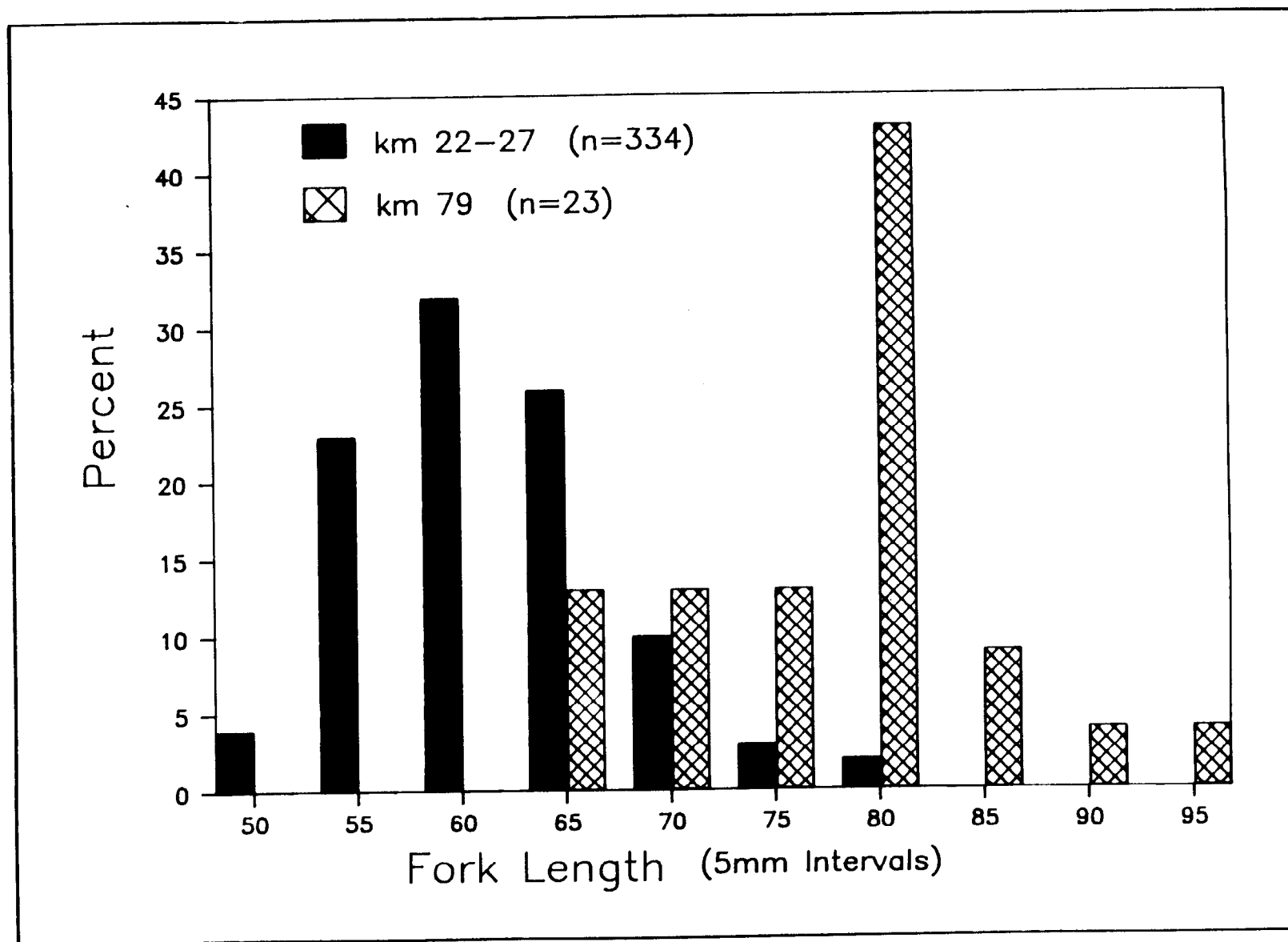
Figure 11. Length frequency plots for coded-wire tagged chinook salmon captured in the lower Kenai River (river km 22-27) and near the outlet of Skilak Lake (river km 79), 1988.

DISCUSSION

Seasonal Distribution and Relative Abundance of Chinook Salmon

During 1986 to 1988, juvenile fish were captured in the lower 132 km of the mainstem Kenai River using baited minnow traps, a hand-held beach seine, and a substrate sampler from July through April (Bendock and Bingham 1988a, 1988b). Chinook salmon were the most frequently captured species accounting for 89%, 34%, and 18% of the minnow trap, beach seine, and substrate sampler catches, respectively (Figure 12). They were distributed throughout the mainstem Kenai River from Cook Inlet up to Kenai Lake. Other studies support the conclusion that chinook salmon are the dominant species of rearing salmonid utilizing mainstem Kenai River habitats (Burger et al. 1983, Litchfield and Flagg 1986).

Chinook salmon inhabit the mainstem Kenai River throughout the year, however, catch rates and relative abundance decrease dramatically from summer to winter (Figure 13). Major seasonal shifts in distribution are reported for many populations of juvenile salmonids (Bjornn 1971, Swales et al. 1986, Hillman et al. 1987). In our investigation, minnow traps caught the highest proportion (89%) of chinook salmon during the summer period and also showed the greatest disparity between summer and winter catch components. Declines in fall minnow trap catch rates for Kenai River chinook salmon were observed by Burger et al. (1983), Estes and Kuntz (1986), and Litchfield and Flagg (1986). Our data demonstrate the seasonal change in relative abundance of chinook salmon using three different sampling gears. We conclude that fewer chinook salmon inhabit the mainstem Kenai River in winter months than in summer months and that gear bias or behavioral changes can not fully explain the disparity in seasonal catch rates.

Juvenile chinook salmon in a number of different populations and habitats overwinter beneath rocks, rubble, and other large cover on the stream bottom (Everest 1969, Everest and Chapman 1972). This behavior is thought to protect juvenile fish from unprofitable energy expenditure, predation, ice-scour, and downstream displacement (Hartman 1963, Bustard and Narver 1975). Burger et al. (1983) interpreted the fall declines in minnow trap catch rates as a movement by juvenile chinook salmon away from shore and into river reaches having larger substrates (river km 33.6 to 56.0). Litchfield and Flagg (1986) captured juvenile chinook salmon overwintering in the substrate of the Kenai River and demonstrated that some fraction of the overwintering population remains at the same location from fall until spring. We estimated the density of overwintering chinook salmon in two Kenai River reaches during three time periods (Bendock and Bingham 1988b). Our results indicate that chinook salmon occupied interstitial substrate spaces and submerged mats of aquatic vegetation during early winter (November); however, the density of overwintering chinook salmon continued to decline significantly as winter progressed (Figure 14). Our lower study reach was suspected to be the over-wintering destination of lower river chinook salmon (Burger et al. 1983), while our upper study reach produced the highest summer catch rates during 3 years of study (Litchfield and Flagg 1986); yet winter chinook salmon densities in both of these reaches declined to zero or near zero in our investigation. We conclude that major seasonal shifts in distribution occur

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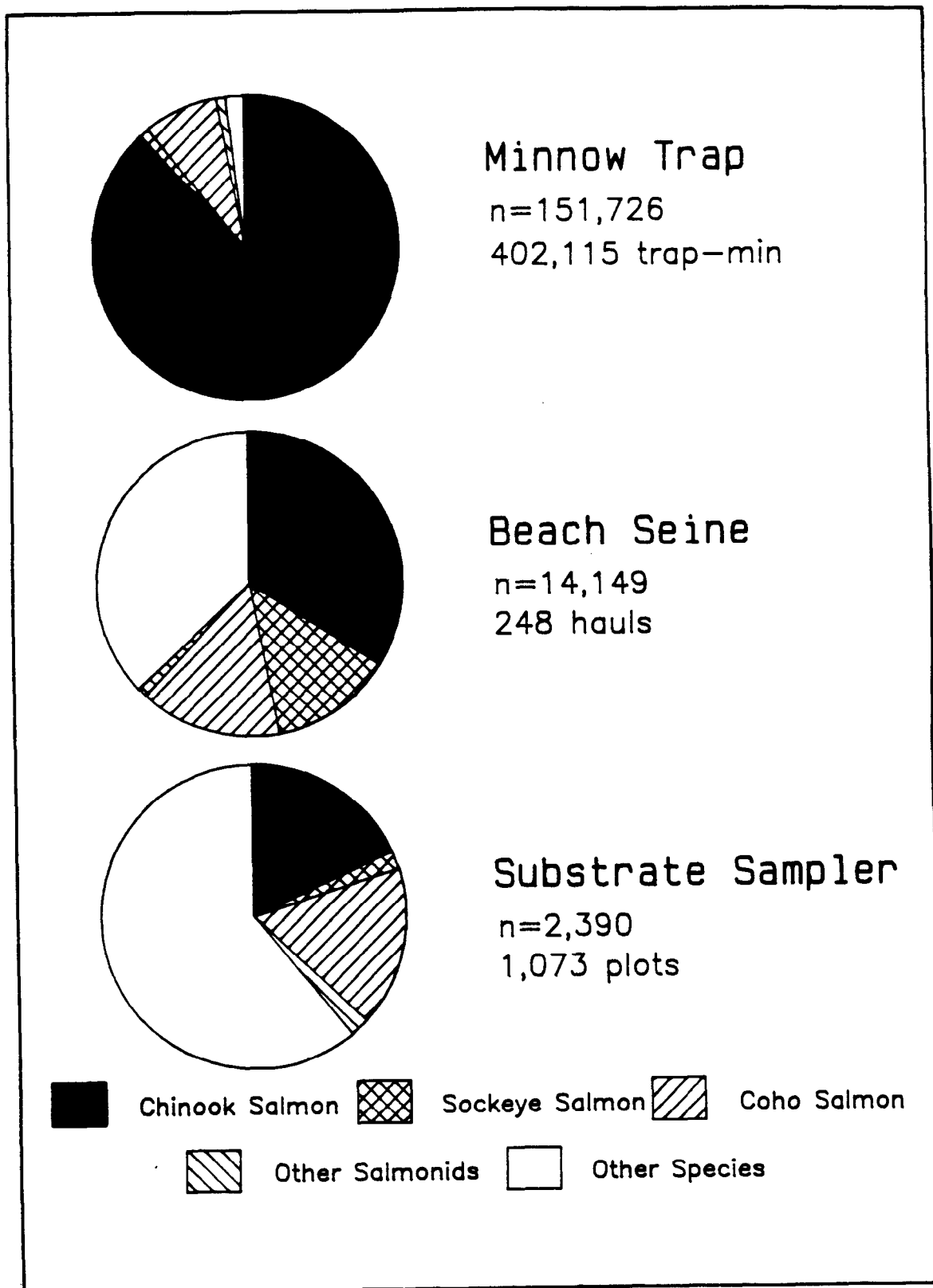Figure 12. Catch composition using three sampling gears in the mainstem Kenai River from July through April during 1986 to 1988.
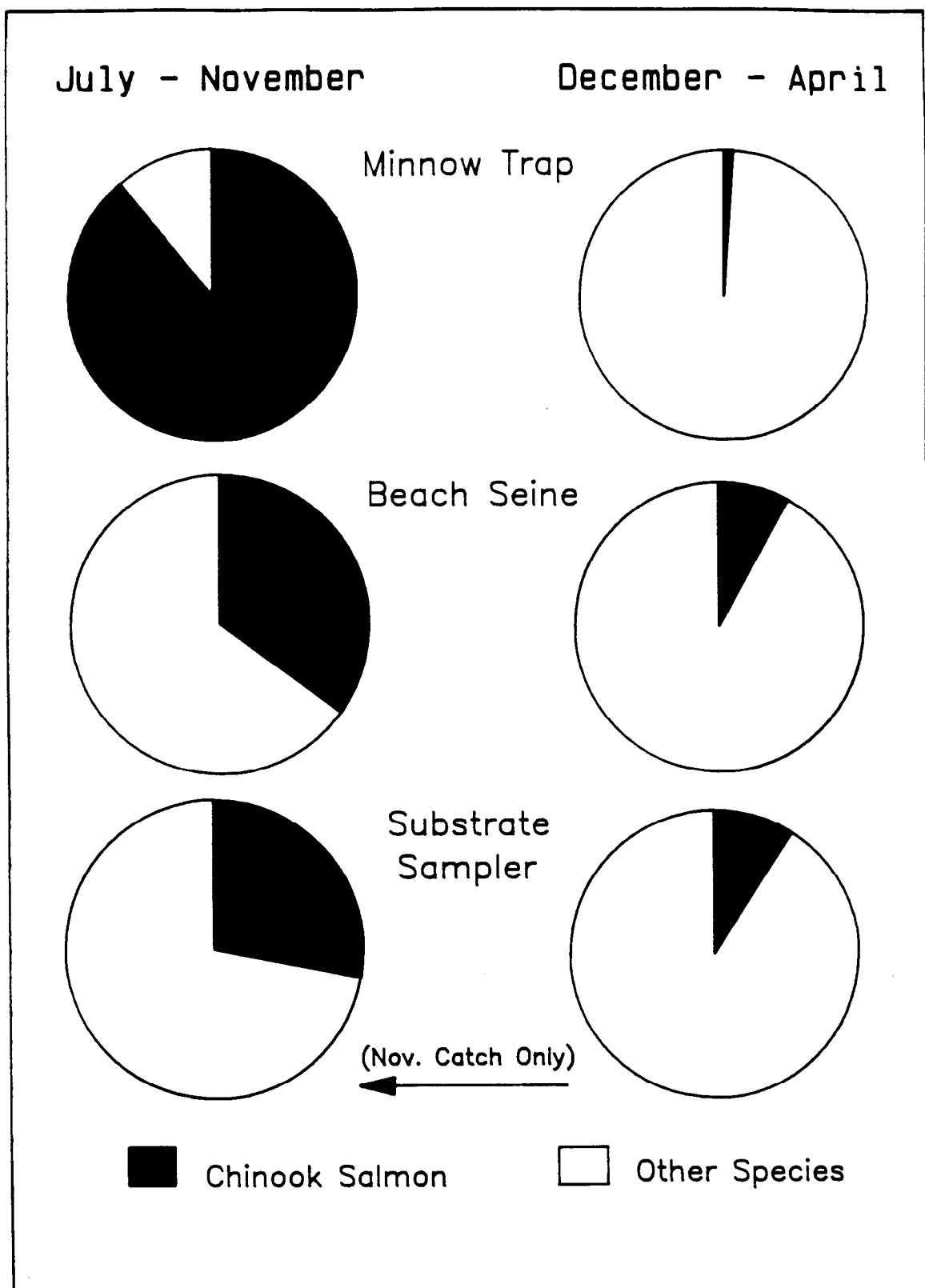
Figure 13. Relative abundance of chinook salmon in the mainstem Kenai
River for two seasonal strata using three sampling gears
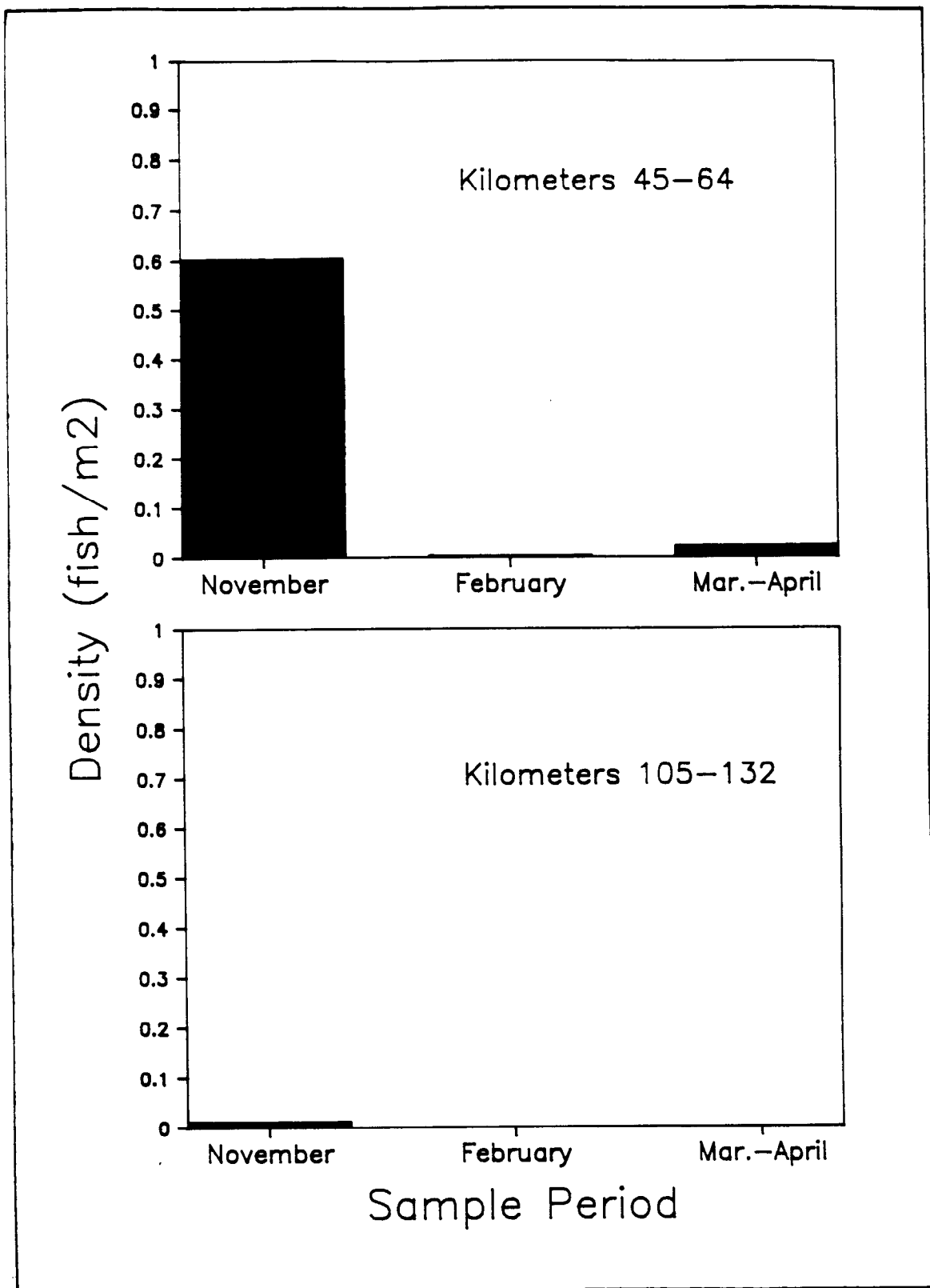during 1986 to 1988.

Figure 14. Density of overwintering juvenile chinook salmon in two
mainstem Kenai River reaches for three sampling periods
during 1987 to 1988.

which result in the exodus of chinook salmon from Kenai River mainstem habitats during winter months.

Results presented in this report demonstrate the mobility of age 0 chinook salmon and indicate that lower river fish are capable of lakeward migrations in excess of 56 km. While some chinook salmon do overwinter in the mainstem and tributaries to the Kenai River (Litchfield and Flagg 1986, Bendock and Bingham 1988a and b), our investigations of the seasonal distribution, winter density, and movements of chinook salmon suggest that the largest fraction of the population departs the mainstem during the fall and overwinters in the large inter-drainage lakes. Lakes have not been previously documented as significant rearing or overwintering habitats for chinook salmon. This may be the result of an absence of lakes in chinook salmon drainages previously investigated, or a failure to include lakes in studies of habitat preference and distribution. Lakes have been documented as important to several other species of salmonids (Raleigh 1967, Northcote 1969, Hutchings 1986, Swales et al. 1988). Burger et al. (1985) identified specific chinook salmon spawning areas in the Kenai River drainage but did not identify the use of lakes for spawning. Thus, the presence of juvenile chinook salmon in Skilak Lake (Figure 7) is the result of immigration from mainstem habitats. Hutchings (1986) found that juvenile Atlantic salmon *Salmo salar* in Newfoundland made extensive use of lakes for rearing and overwintering. The adaptive significance of lakeward migrations by Atlantic salmon was exemplified by increased growth and survival of lacustrine parr relative to riverine parr. The importance of large lakes in the Kenai River drainage to the production of chinook salmon and unrestricted access to these waters by juvenile fish should be considered when developing management practices for stream-side habitats.

Habitat Preferences for Age 0 Chinook Salmon

Throughout the mainstem, chinook salmon occupy a relatively narrow band of nearshore water that is characterized by low velocities resulting from bank irregularities and the presence of cover. Optimum mean water column velocities for juvenile chinook salmon greater than 50 mm in fork length are less than 15 cm/sec (Everest and Chapman 1972, Burger et al. 1983), while velocities greater than 60 cm/sec (2 ft/sec) usually exclude rearing chinook salmon. Velocity and cover appear to be the most important variables influencing habitat usability for rearing chinook salmon in the mainstem Kenai River (Burger et al. 1983, Estes and Kuntz 1986, Litchfield and Flagg 1986, Bendock and Bingham 1988a and b). However, efforts to describe the relationship between habitat usability and chinook salmon catch have been largely unsuccessful in this river. Possible explanations for this include: 1) fish abundance early in the season correlates with the distribution of natal areas rather than preferences for habitat types; 2) suitable summer habitat is abundant throughout the mainstem making preferences among a selection of suitable habitat types difficult to quantify; 3) movement during juvenile stages is extensive resulting in the ephemeral use of a particular habitat type; and 4) distributions are the result of innate behaviors that are only slightly modified by extrinsic factors.

Bendock and Bingham (1988b) did not find significant interactions between chinook salmon catch rates and sample site depth, velocity, substrate size,

or macrohabitat type at sites having instream or riparian cover during July and August. In the absence of cover, variability in catch rates was explained by velocity and substrate size. Winter densities were significantly related to cover type and sample periods. Estes and Kuntz (1986) found significant differences in catch rates between habitat types during October but did not find similar differences during July. These data suggest that during mid-summer, juvenile chinook salmon exploit a wide range of readily available habitat conditions in the mainstem Kenai River and that conditions of depth and velocity along stream banks that were sampled were within the suitable limits described for chinook salmon by Burger et al. (1983). Minnow trap catch rates obtained in this study (Table 2) tend to support the above conclusion and characterize a summer distribution for chinook salmon that is relatively uniform along the stream margin. Mean catch rate and variability increased during September suggesting a clumped distribution and stronger preference for specific sites.

The seasonal variability in chinook salmon catch rates and catch components from minnow trap samples in the Kenai River indicate that use of a particular site is ephemeral and that movement within the mainstem is frequent and extensive (Figure 15). The sharp decline in chinook salmon relative abundance during September and October correlates with commensurate declines in stream discharge and water temperature (Figure 16). Declines in discharge and temperature and the consequent reduction of bank cover may elicit migratory behavior in juvenile chinook salmon and corresponds to the period when marked fish from the lower Kenai River were recovered in fyke traps near the outlet of Skilak Lake. This argument is weakened, however, by the fact that all chinook salmon do not leave the mainstem to overwinter in the lake (Litchfield and Flagg 1986, Bendock and Bingham 1988a and b). Migrant chinook salmon were significantly larger than fish that remained in the lower river (Figure 11). If size is positively correlated with fitness, then larger juveniles could be expected to adapt behaviors that would enhance growth and survival, and movements into Skilak Lake could represent an alternative reproductive tactic rather than a response to environmental factors (Hutchings 1988). In Newfoundland, approximately 10% of Atlantic salmon parr overwintered in lakes, yet lakes accounted for the majority of smolts leaving the system (Hutchings 1988). Information on the proportional contribution of smolts leaving the Kenai River system is not available.

Habitat Management Practices for the Kenai River

The present rationale to develop habitat management guidelines for the Kenai River based on habitat type and river reach (ADNR 1986) depends on three underlying assumptions: (1) juvenile salmon remain in fluvial habitats throughout their fresh water residency; (2) movement during juvenile stages is limited or infrequent; and (3) that a positive relationship exists between juvenile fish abundance and habitat type or river reach. Information obtained in the past 3 years suggests that the above assumptions may be inappropriate for juvenile chinook salmon in the Kenai River drainage. Our results suggest that clear and significant relationships between chinook salmon abundance and habitat types in the mainstem Kenai River are difficult to establish and may only persist for a few weeks of the year, that the mainstem population of juvenile chinook salmon is mobile and movements are
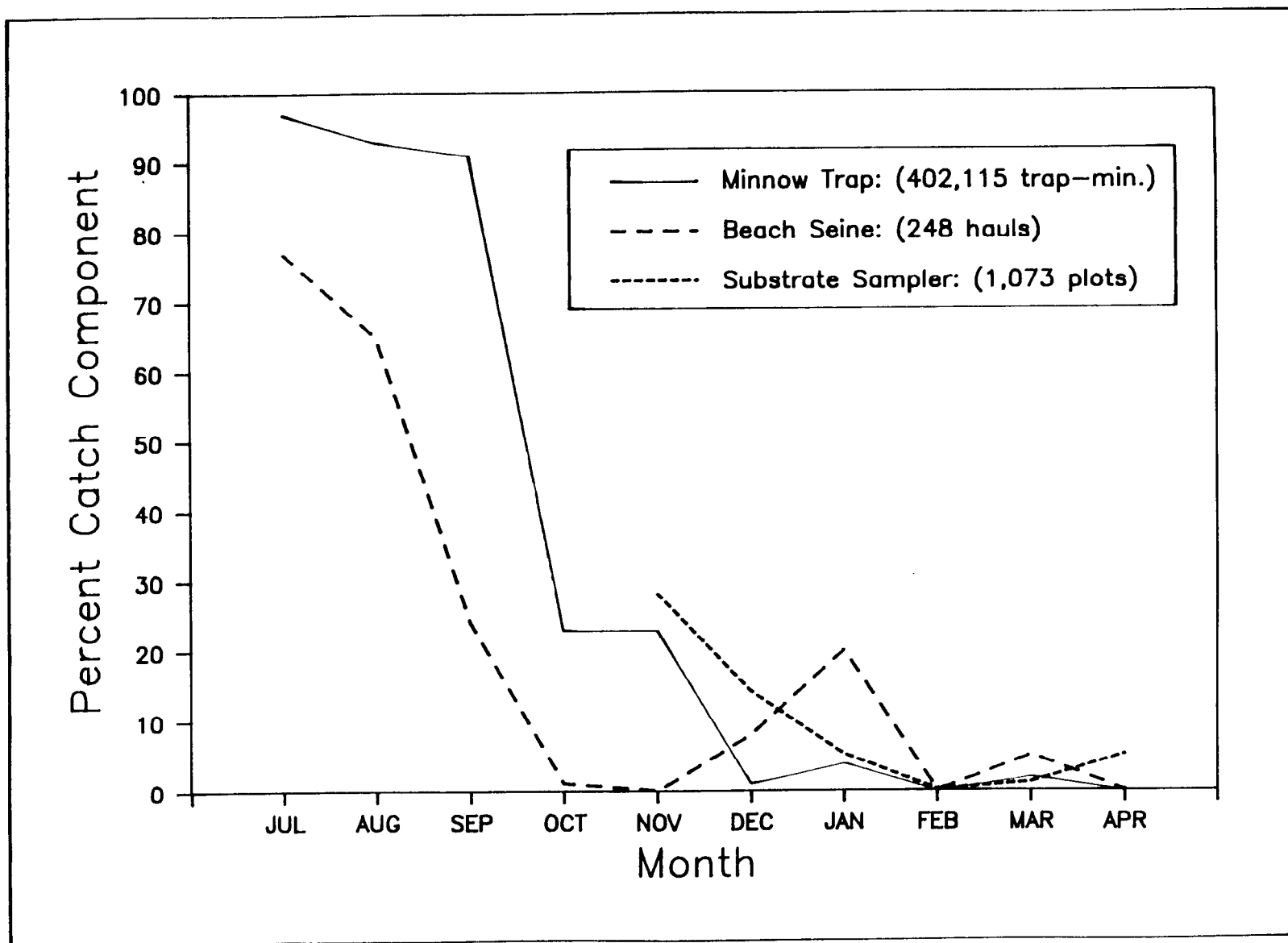
Figure 15. Seasonal variation in chinook salmon catch components for three sampling gears used in the mainstem Kenai River during 1986 to 1988.
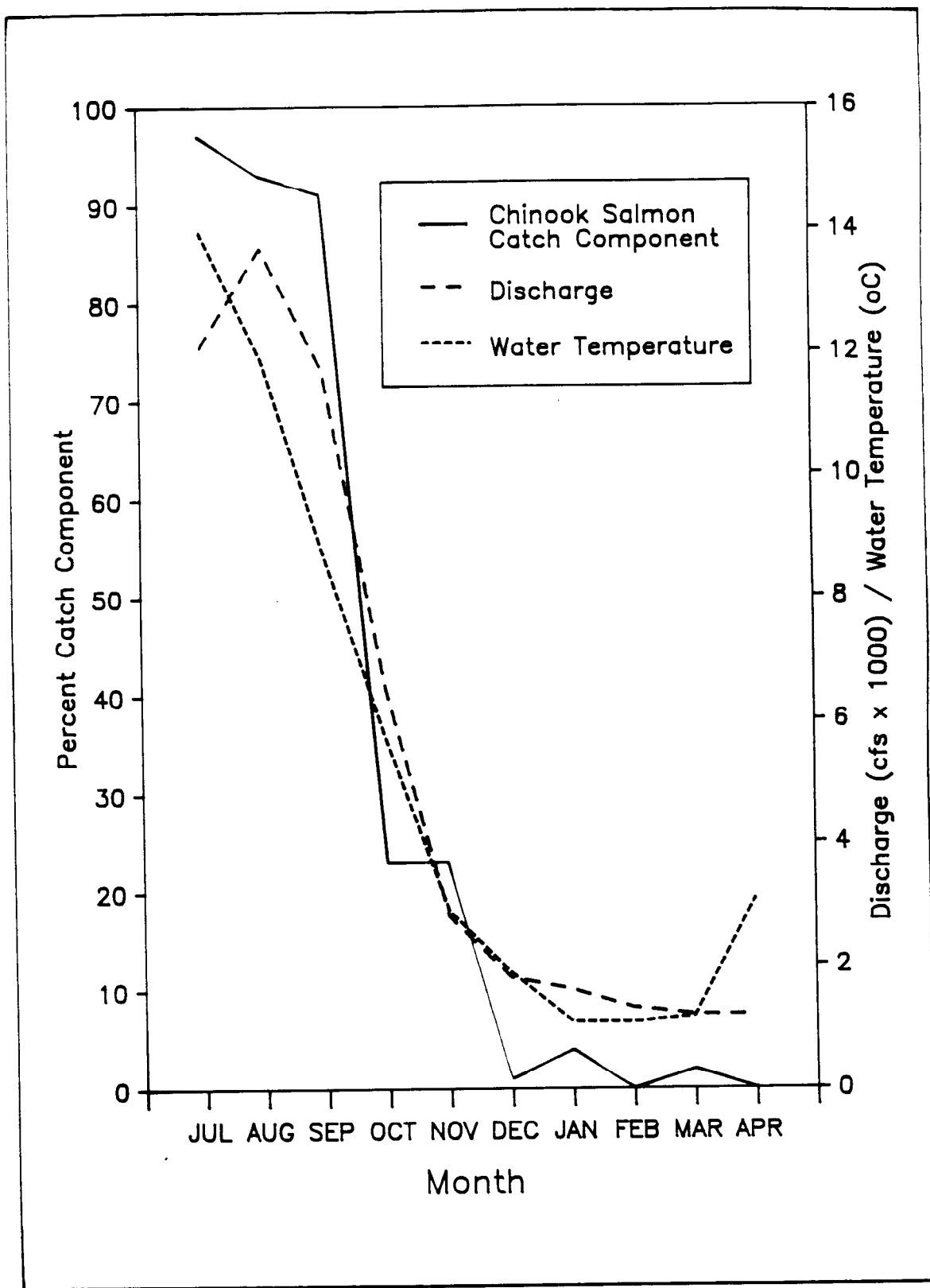
Figure 16. Seasonal variation in discharge, water temperature, and chinook salmon relative abundance for the mainstem Kenai River.

extensive, and that Skilak Lake is used for rearing and overwintering by a portion of the juvenile population which emigrates from the mainstem. Previous studies did not address the importance of Skilak or Kenai Lakes to chinook salmon production even though these lakes exert a considerable influence on the physical, chemical, and hydrological characteristics of the mainstem and constitute a significant component of available habitat within the river drainage. Further investigation is needed to identify the extent of lake use by juvenile salmon for rearing, overwintering, and smolt production.

Habitat management practices for the mainstem Kenai River should be established to protect the present diversity of naturally occurring habitat conditions, and provide unrestricted access for juvenile fish along both shorelines between tidewater and Kenai Lake. Chinook salmon are the species most likely to be affected by adverse development in the Kenai River due to their preference for mainstem habitats, continuous distribution, high relative abundance, and migratory behavior. The population of juvenile chinook salmon arises from multiple (and possibly distinct) spawning stocks. However, there is currently no evidence that discrete groups of juveniles remain segregated during their freshwater residency. Thus, for permitting purposes, the mainstem population may be viewed as a mobile, single population that ranges extensively throughout the drainage. Permit criteria that maintain suitable habitat values should be developed and applied uniformly along the mainstem of the Kenai River. A differential approach to land-use permitting within the mainstem may over-value some habitat types and under-value others to the detriment of both the resource and adjacent land-owners.

Impacts and Recommendations for Instream Developments

Present instream developments along the Kenai River include floating docks, excavated canals, boat basins and launching ramps, groins, and several types of bank revetments. Off-channel habitats including boat basins and canals were not investigated in this study but were reviewed along with boat ramps and floating docks by Burger et al. (1983). There is an increasing interest in bank stabilization structures by adjacent property owners and potential impacts from these activities and existing groins are discussed below.

Bank Stabilization:

Structures designed to protect private property from excessive erosion were reviewed in the Kenai River Comprehensive Management Plan (ADNR 1986) and found to be an appropriate use of the mainstem Kenai River when they are designed to protect and enhance fishery habitat. Bank stabilization structures can alter the cover, depth, shoreline slope, substrate, and velocity characteristics of the natural stream bank. While our results indicate that use of a particular bank by juvenile chinook salmon is ephemeral, it is reasonable to assume that continuity of suitable shoreline habitat allows exploitation over a broad area and disrupting that continuity may result in less favorable rearing conditions. The cumulative effects of these structures must also be considered in view of the movements undertaken by age 0 chinook salmon. Juvenile chinook salmon migrating from the lower Kenai River to Skilak Lake encounter every obstacle in route to their destination.

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Obstacles located high in the drainage will affect a larger proportion of the migratory population than similar structures located low in the drainage. A single obstacle may be of little consequence but cumulative obstacles likely result in increased mortality for migrating chinook salmon.

Bank stabilization structures should maintain the natural slope and contour of the shoreline to minimize changes in water velocity. Fill materials should consist of large rubble or cobble. In addition to providing a rough surface to reduce velocity, large fill material provides cover for chinook salmon and potential overwintering habitat (Everest 1969, Swales et al. 1986, Hillman et al. 1987, Bendock and Bingham 1986a and b).

Increasing water velocity results in the downstream displacement of juvenile salmonids and can result in 'wash-out' if low velocity areas along the bottom or shoreline are not accessible to juvenile fish. Sensitivity to flow decreases as water temperature and fish size increases (Everest and Chapman 1972, Taylor 1988). Heggenes and Traaen (1988) demonstrated that juvenile salmonids could tolerate velocities greater than 50 cm/sec when the fry had reached 40 to 50 mm; however, Irvine (1986) suggested a longer flow-sensitive period for juvenile chinook salmon. Burger et al. (1983) captured 80% of the 51 to 100 mm chinook salmon in velocities below 33 cm/sec in the Kenai River. Bendock and Bingham (1988b) estimated a mean water column velocity of 23 cm/sec at stations located 1.2 m from shore at 64 randomly selected sites in the Kenai River, and a mean water column velocity of 13.2 cm/sec at stations located 0.6 m from shore. Thus, maintaining low water velocities is critical for continued fish use of altered banks.

Bank stabilization structures that require fill material usually result in the loss of bank vegetation and instream debris which provides cover for juvenile chinook salmon. Bendock and Bingham (1988b) showed that in the absence of instream or riparian cover, catches of juvenile chinook salmon were significantly related to velocity, depth, and substrate conditions. Catches of chinook salmon increased as substrate size and depth increased but decreased as velocity increased. These relationships were not significant at sites having instream or riparian cover. Thus, the addition of instream or riparian cover at bank stabilization structures will mitigate adverse effects of depth, velocity, and substrate values.

The timing for construction of bank stabilization structures should coincide with the period of minimum fish use along the shoreline. Discharge in the Kenai River rises beginning in May followed by high levels throughout the summer and declines to sustained low levels from January through April (Scott 1982). The period of low discharge from January through April corresponds to the time of minimum chinook salmon abundance in the mainstem Kenai River (Figure 16). Emergent salmonids begin to seek refuge along stream banks as water temperatures and discharge increase during May. Impacts to juvenile fish will be minimal if construction activities take place during the period of low discharge. Knudsen and Dilley (1987) evaluated the effects of riprap reinforcement on juvenile salmonids and concluded that the negative short-term effects of construction increased with severity of habitat alteration, decreased with increase in stream size, and decreased with increasing fish size.

Groins:

Groins are structures placed at approximately a right angle to the bank and are commonly used in the Kenai River to provide docking facilities and a protected area for boat mooring (Scott 1982). The Kenai River Comprehensive Management Plan (ADNR 1986) recognized groins as non-compatible river structures due to their negative impacts on stream hydrology and juvenile fish rearing habitat. Groins may displace the river channel towards the opposite bank a distance equivalent to the length of the structure. Flow that is obstructed by groins falls across or around the tip of the structure where velocities can exceed 130 cm/sec and pools with little or no velocity form at the downstream base.

It is unlikely that new groins will be permitted for the Kenai River; however, existing groins represent the most significant man-made obstruction to the passage of juvenile salmonids in the mainstem Kenai River. In 1985, there were at least 68 groins in the mainstem Kenai River between Kenai Lake and Cook Inlet (KRSMA 1985). Groins were found to decrease usable habitat for rearing salmon in the Kenai River. Chinook salmon were absent from groin areas where velocity was eliminated or where velocities exceeded 60 cm/sec (Burger et al. 1983). Our findings on the movements of age 0 chinook salmon add to the evidence that these structures are deleterious to chinook salmon production in the Kenai River. Accelerated velocity around the tip of a groin presents a barrier to juvenile chinook salmon migrating along the shoreline. Barriers may disrupt the use of contiguous habitats, force juvenile fish to seek alternative routes around the structure, exhaust fish following unsuccessful attempts to pass, or concentrate juvenile migrants and expose them to piscivorous predators. The cumulative effects from passing numerous groins between the lower river and overwintering habitat in Skilak Lake likely results in increased mortality for migrating juvenile chinook salmon. The adverse effects from groins in the Kenai River should be mitigated by either removing the structures or by making them permeable and thus allowing the passage of water and juvenile fish between the tip and shoreline.

Conclusions:

1. Chinook salmon are the species in the mainstem Kenai River most likely to be affected by instream activity and bank development.

2. Chinook salmon disperse from relatively limited areas of emergence to exploit the entire Kenai River mainstem for rearing.

3. Chinook salmon summer rearing habitat is contiguous along the shoreline of the mainstem Kenai River.

4. Movements of juvenile chinook salmon are frequent and extensive within the mainstem Kenai River.

5. Habitat diversity and availability in the Kenai River varies seasonally which accounts for dramatic changes in the relative abundance of juvenile chinook salmon.

6. Juvenile chinook salmon depart mainstem habitats during the fall to overwinter in Skilak Lake.

7. The presence or absence of cover is the best determinant of chinook salmon habitat preference.

8. In the presence of instream or riparian cover, chinook salmon catch rates do not vary significantly due to macrohabitat type, substrate size, depth, or velocity.

9. In the absence of cover, catch rates vary significantly due to substrate size, depth, and velocity.

10. The addition of cover in a shoreline development project can mitigate adverse changes in depth, velocity, and substrate characteristics, provided these habitat conditions remain within suitable limits.

11. Development activities in the mainstem Kenai River should coincide with the period of minimum fish use (December through April).

12. Groins (jetties) are the most significant man-made obstruction to the movement of juvenile fish between contiguous summer rearing habitats and overwintering areas in the Kenai River.

13. Juvenile fish survival is likely affected by the cumulative impacts from multiple structures in the mainstem Kenai River.

14. Due to the migratory behavior of juvenile chinook salmon, structures located high in the drainage will affect a larger fraction of the population than similar structures located low in the drainage.

15. Permit guidelines that protect or enhance habitat values for juvenile chinook salmon should be uniformly applied throughout the mainstem Kenai River.

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APPENDIX

Appendix Table 1. List of common names, scientific names, and abbreviations for fish that inhabit the Kenai River.

Family Common Name	Scientific Name	Abbreviation
Salmonidae		
Chinook Salmon	*Oncorhynchus tshawytscha* (Walbaum)	KS
Sockeye Salmon	*Oncorhynchus nerka* (Walbaum)	RS
Coho Salmon	*Oncorhynchus kisutch* (Walbaum)	SS
Pink Salmon	*Oncorhynchus gorbuscha* (Walbaum)	PS
Chum Salmon	*Oncorhynchus keta* (Walbaum)	CS
Rainbow Trout	*Oncorhynchus mykiss*	RT
Dolly Varden	*Salvelinus malma* (Walbaum)	DV
Lake Trout	*Salvelinus namaycush* (Walbaum)	LT
Arctic Grayling	*Thymallus arcticus* (Pallas)	GR
Round Whitefish	*Prosopium cylindraceum* (Pallas)	RWF
Bering Cisco	*Coregonus laurettae* Bean	BCI
Cottidae		
Coastrange Sculpin	*Cottus aleuticus* Gilbert	CSC
Slimy Sculpin	*Cottus cognatus* Richardson	SSC
Pacific Staghorn Sculpin	*Leptocottus armatus* Girard	PSC
Gasterosteidae		
Threespine Stickleback	*Gasterosteus aculeautus* Linnaeus	TST
Ninespine Stickleback	*Pungitius pungitius* (Linnaeus)	NST
Petromyzontidae		
Pacific Lamprey	*Entosphenus tridentatus* (Gairdner)	PLP
Arctic Lamprey	*Lampreta japonica* (Martens)	ALP
Catostomidae		
Longnose Sucker	*Catostomus catostomus* (Forster)	LNS
Osmeridae		
Eulachon	*Thaleichthys pacificus* (Richardson)	HOO
Longfin Smelt	*Spirinchus thaleichthys* (Ayres)	LSM
Esocidae		
Northern Pike	*Esox lucius* Linnaeus	NP
Clupeidae		
Pacific Herring	*Clupea harengus pallasi Valenciennes*	*PH*
Pleuronectidae		
Starry Flounder	Platichthys stellatus (Pallas)	SFL
Gadidae		
Pacific Tomcod	*Microgadus proximus* (Girard)	TCD
Cyclopteridae		
Snailfish	Liparis spp	LIP
Stichaeidae		
Slender Eelblenny	*Lumpenus fabricii* (Valenciennes)	SE